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Butterfly communities in remnant and reconstructed prairies in Central Iowa, U.S.A

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General Introduction

Introduction

The loss of the prairie ecosystem in the Midwestern United States has been substantial. In Iowa, only 0.1 % of the original 28.8-31.3 million acres of prairie still remains (Smith 1998). Most areas that were formerly prairie are now in agricultural production and this dramatic alteration of the landscape has had impacts on the flora and fauna that are associated with prairie ecosystems (Schlicht & Orwig 1998; Smith 1998).

Restoration or reconstruction of the prairie ecosystem is one method being used to reverse the trend of prairie loss (Jordan et al. 1987; Hobbs 1993; Packard & Mutel 1997; Smith 1998). Prairie restoration is defined as the enhancement of a degraded remnant prairie, while prairie reconstruction refers to the re-creation of prairie from plowed (bare) ground (Packard & Mutel 1997). The two studies presented in this thesis focus on reconstructed prairies in Central Iowa. The ideal goal for most prairie reconstruction projects is to re-create as closely as possible a functioning and diverse prairie ecosystem (Jordan et al. 1987; Packard & Mutel 1997).

Reconstructing ecosystems with all the functioning components of a remnant natural ecosystem has been a challenge (Jordan et al. 1988). Many reconstruction projects focus primarily on establishing and assessing the plant community because of the central role vegetation plays in ecosystem function and structure (Hobbs 1993). However, due to gaps in scientists' understanding of how to recognize and restore important interactions between organisms in an ecosystem (Jordan et al. 1987, Hobbs & Norton 1996), an exclusive focus on a reconstructed plant community may not be adequate to fully and accurately assess the development of a reconstruction project (Panzer & Schwartz 1998, Reay and Norton 1999).

A number of studies have examined the use of arthropods in supplementing or replacing plants in the assessment of the development and success of reconstruction projects (Erhardt & Thomas 1991; Williams 1993; Anderson & Sparling 1997; Jansen 1997; Wheater & Cullen 1997; Bisevac & Majer 1999; Reay & Norton 1999). Insects are proposed as good indicators of reconstruction success because of their diversity and tight relationship with the plant community (Hendrix et al. 1988). In particular, butterflies may be excellent indicators especially in grassland ecosystems where they are abundant.

Adult butterflies are easy to sample and have been suggested as indicators of ecosystem health by a number of authors (Erhardt & Thomas 1991; Kremen 1992; Panzer et. al. 1995; Holl

1996; Hammond & Miller 1998; Brown & Freitas 2000). The Lepidoptera contain a large but not overwhelming number of species (50-60 species in Iowa prairies), which exhibit varying degrees of habitat specificity and disturbance sensitivity (Panzer et. al. 1995; Holl 1996; Schlicht & Orwig 1998). They could, therefore, be very useful in the assessment of reconstruction quality and development.

In addition, open areas and grasslands are important habitat for butterflies, and several species that depend on grassland habitat are declining and are endangered or threatened (e.g., *Speyeria idalia, Oarisma poweshiek, Hesperia dacotae, Hesperia ottoe, Coenonympha tullia*)(Schlicht & Orwig 1998). Restoration may play a critical role in the survival of these and other prairie endemic butterflies (Orwig 1990; Debinski and Kelly 1998; Schlicht and Orwig 1998).

We present two studies in this thesis that examine butterfly populations and communities on reconstructed prairies in Central Iowa. We assess the utility of the butterfly community as indicators of reconstruction quality. We also determine whether a reconstructed prairie is capable of supporting a viable population of a reintroduced rare prairie endemic butterfly, *Speyeria idalia.*

Thesis Organization

Chapter two details a study examining butterfly community properties in reconstructed prairies of different vegetation quality. Plants and butterflies were surveyed on 24 reconstructed prairies and 12 remnant prairies that served as reference communities. The reconstructed prairies were divided into isolated reconstruction sites that existed in an agricultural (inhospitable) matrix and integrated sites that existed in a larger matrix of reconstructed and remnant prairie. Prairies in each of the three treatments (remnant, isolated reconstructions, and integrated reconstructions) existed along a vegetative quality gradient defined by plant diversity, the proportion of native to non-native plant species richness, and plant composition. Butterfly abundance, richness, and composition were compared among prairies of different type (remnant, isolated reconstructions, and integrated reconstructions) and reconstructed prairies of different vegetative quality. The importance of different vegetative components to butterfly richness and abundance is also assessed. Full methods and results of this study are presented and discussed in Chapter 2. Chapter 2 will be submitted for publication in *Conservation Biology.*

Chapter three details efforts between 1998 and 2002 to reintroduce *Speyeria idalia*, a prairie endemic butterfly, to Neal Smith National Wildlife Refuge, a 1,250- hectare reconstructed prairie in Jasper County, IA. In 1998 and 1999, 1,980 individuals of *S. idalia*'s host plant *Viola pedatifida* were planted in four different areas in the central part of the refuge. In 2000 and 2001, following host plant establishment, a total of seven gravid *S. idalia* females were moved from Ringgold Wildlife

Area and Rolling Thunder State Preserve, and placed in mesh cages over the violet plots at Neal Smith NWR. Results from the host plant establishment and butterfly reintroduction are presented and discussed in Chapter three. Chapter three will be submitted for publication in *Restoration Ecology*.

Chapter four is a general conclusion of both primary studies and it addresses how butterfly communities as well as a habitat specific butterfly species respond to prairie reconstructions in Iowa. The overall results from Chapters two and three are summarized and the implications of both studies are discussed. Chapter four will not be submitted for publication.

There are two authors listed for both Chapters two and three. Stephanie Shepherd is graduate student in the Interdepartmental Program of Ecology and Evolutionary Biology and was the primary researcher and author. Dr. Diane Debinski is an associate professor in the department of Ecology, Evolution and Organismal Biology. All research and writing was done under Dr. Debinski's supervision and guidance.

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The utility of butterflies as indicators of the vegetative quality of prairie reconstructions

A paper to be submitted to *Conservation Biology*

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Abstract: *Reconstructing prairie habitat is one of the most promising techniques for conserving the imperiled prairie ecosystem and its associated organisms. However the degree to which reconstructed prairies function like remnant prairies has not been fully examined. Assessment of plant and animal communities on restorations relative to prairie remnants will provide valuable feedback on restoration efforts. We evaluated the effect of restoration planting prescriptions, management, and vegetative quality on butterfly communities inhabiting prairie reconstructions in central Iowa, USA. Twelve isolated reconstructed prairies (small, surrounded by agriculture), 12 integrated reconstructions (planting units in a larger matrix of reconstructed and remnant prairies), and 12 remnant prairies were surveyed for butterfly and plant diversity, abundance and composition. Sites within each group were selected to represent a vegetative diversity gradient. We found that remnant prairies supported higher butterfly richness and plant diversity ($p < 0.01$) but were not significantly different from reconstructions in butterfly species composition and abundance. However, richness($p < 0.03$) as well as abundance ($p < 0.008$) of habitat-sensitive butterfly species was higher on remnants when compared to reconstructions and disturbance tolerant species exhibited no differences among prairie types. Prairies that had been burned in the spring or fall preceding surveys supported lower butterfly richness than those without recent burning ($p < 0.04$). Reconstructions that were the most similar to remnant prairies in plant diversity, % native plant species, and average coefficient of conservatism (vegetative quality) did not support significantly different butterfly communities based on measures of butterfly richness, abundance and composition though butterfly richness and abundance were highest on high quality reconstructions. A trend towards higher butterfly richness on integrated reconstructions when compared to isolated reconstructions was also noted. Finally, the best vegetative predictors of butterfly richness ($R^2 = 0.38$) and abundance ($R^2 = 0.13$) were the number of ramets in bloom (nectar availability) and the % cover of duff. In conclusion, adult butterflies seem to be limited indicators of the vegetative quality of reconstructed prairies in Iowa. Reconstructed prairies do provide important habitat for butterflies and care should be taken when planning and managing projects to consider both flora and faunal components of the prairie community.*

Introduction

Arguably one of the fastest developing segments of conservation biology is the practice and theory of restoration ecology (Jordan et al. 1988). Restoration ecology can loosely be defined as the process of repairing or recreating natural ecosystems that have been damaged by the actions of humans (Jackson et al. 1995). Ecological restoration is unique in a number of ways, the most basic of which is a shift in goals from the preservation of relatively pristine natural areas to the restoration or reconstruction of degraded or destroyed ecosystems.

From a conservation perspective, the re-creation of a productive natural landscape is needed in areas of high anthropogenic influence and alteration (Jordan et al. 1988; Hobbs 1993; Recher 1993), such as the restoration of tallgrass prairie and wetlands in Iowa, USA. Pre-European settlement Iowa contained approximately 7.6 million acres of prairie marsh-pothole wetlands, which by 1980 was reduced to 30,000 acres (Bishop et al. 1998). Perhaps a more striking statistic is the loss of prairie, which in Iowa occupies only 0.1 % of its historical area of 28.8 to 31.3 million acres because of extensive conversion of land to agriculture (Smith, 1998). In light of these statistics, it is clear that prairie restoration in Iowa, by adding areas of natural vegetation, will have a larger conservation impact than exclusively preserving the few, small existing prairie remnants in isolation (Hobbs 1993). As a result, several prairie restoration projects have been initiated in the last 15 years in a variety of situations throughout the state.

One component of a restoration project that many professionals recognize as key is the assessment of restoration success (or failure) (Ewel 1987; Harper 1987; Westman 1991; Saunders et al. 1993). Ideally, the goal of restoration and reconstruction is to restore the floral, faunal and abiotic components, as well as the interactions between these components, that exist on an intact, naturally functioning ecosystem (Hobbs 1993; Jackson et al. 1995). Eventually the site will not only look, but also function like a prairie from the perspective of ecosystem processes, and trophic interactions. However, assessments of restoration projects often focus exclusively on the plant community due to its central structural role but the importance of evaluating other elements of the ecosystem is being recognized; in particular the potential of the arthropod community to serve as indicators of ecosystem development (Erhardt & Thomas 1991; Williams 1993; Anderson & Sparling 1997; Jansen 1997; Wheater & Cullen 1997; Bisevac & Majer 1999).

Here we examine butterfly communities as indicators of prairie reconstruction success. Butterflies are a logical group for study because of their role as important herbivores, and pollinators and their association with the plant community (Scott 1986; Hendrix & Kyhl 2000). Adult butterflies are easy to sample and have been suggested as indicators of ecosystem health (Erhardt & Thomas 1991; Kremen 1992; Panzer et. al. 1995; Holl 1996; Hammond & Miller 1998; Brown & Freitas 2000). The Lepidoptera contain a large but not overwhelming number of species (50-60 species on Iowa prairies), which exhibit varying degrees of habitat specificity and disturbance sensitivity (Opler and Krizek 1984; Scott 1986; Panzer et. al. 1995; Schlicht and Orwig 1998). They could, therefore, be very useful in the assessment of reconstruction quality or similarity to remnants. In addition, open areas and grasslands are important habitat for butterflies, and several species that depend on grassland habitat in North America are in decline (e.g., *Speyeria idalia*, *Oarisma poweshiek*, *Hesperia dacotae*, *Hesperia ottoe, Coenonympha tullia*) (Schlicht & Orwig 1998). Restoration may play a critical role in the survival of these and other prairie endemic butterflies (Orwig 1990; Debinski and Kelly 1998; Schlicht and Orwig 1998).

For the purposes of this study, reconstructed prairie was defined as the re-creation of a destroyed ecosystem, which in central Iowa most often is the conversion of a former crop field into prairie vegetation. We examined relationships between aspects of the vegetative community and the butterfly community to determine whether the butterfly richness, abundance and species composition could be used to indicate the quality (defined as similarity to remnants) of the restored plant community. We compared reconstructed prairies with several remnant prairies serving as reference communities (Aronson et al. 1995; Kondolf 1995; White & Walker 1997). There is evidence that remnant ecosystems, on average, have higher plant diversity (Wheater & Cullen 1997; Brand & Dunn 1998) and support a higher diversity of butterflies (Selser & Schramm 1990; Panzer et al.1995; Debinski & Babbit 1997).

Secondarily, we assessed how variance in the original planting scheme, goals of a restoration, and the subsequent management were reflected in the butterfly community. Many assessments focus on the age of the restoration project as the primary variable to determine whether success has been attained (van Aarde et al. 1996; Jansen 1997; Brand & Dunn 1998; Bisevac & Majer 1999; Reay and Norton 1999) but the original planting formula and subsequent management may significantly influence the developmental trajectory of the restoration (MacMahon 1987; Chambers et al. 1994; Wheater & Cullen 1997; Bomar 2001). In Iowa, some reconstruction projects begin with the restoration of a highly diverse suite of biologically appropriate plant species, including many conservative (sensitive to disturbance) plant species. However, most reconstruction projects do not focus on biodiversity but rather have alternative goals such as creating habitat for a game species, or erosion control. As a result, there exists a broad diversity in reconstruction vegetative composition and the diversity of plantings provides an ideal situation for studying how variance in the plant community affects the butterfly community.

The questions addressed in this study are: 1) Do remnant prairies in central Iowa support a more diverse butterfly and plant community than reconstructed prairies? 2) Do clustered reconstructions integrated with remnant prairie communities promote more diverse and abundant butterfly communities when compared with small, isolated reconstructions? 3) Do butterflies serve as indicators of vegetative quality (defined as the level of similarity to remnant communities) on reconstructed prairies? 4) What prairie vegetative components are butterfly diversity and abundance most correlated with? and 5) What effect does management of prairie reconstructions have on butterfly communities?

Methods

Study Area

We surveyed the butterfly and plant communities on 36 prairies, located in central Iowa (Fig.1). Twelve of these sites were native prairie remnants chosen as reference sites for comparison with the 24 reconstructed prairies. All reconstructions were planted between 1991 and 1998 (4-11 years old).

Twelve reconstructed sites were units within a much larger reconstruction at Neal Smith National Wildlife Refuge (NWR) in Prairie City, Iowa (Fig. 1). Neal Smith NWR encompasses about 1,250 hectares of reconstructed prairie on a total 2,083 hectares of refuge property. The matrix for these sites was a combination of reconstructed prairie and small prairie remnants present on refuge property. The planting units used for our research however, were never less than 310 meters from a remnant prairie to avoid direct spillover of the remnant's butterfly community onto the reconstructions (in the one instance where the reconstruction and a remnant were 310 meters apart, the two areas were separated by a crop field). In addition, whenever possible we kept more than 200 meters distance between different reconstructed sites, which was the highest minimum distance we could attain between sites fitting vegetative quality criteria. Eleven Neal Smith NWR planting units were planted between 1993 and 1995, and the twelfth in 1998. The mean size of the planting units used as sites was 18.24 (range = 5-42) hectares. The landscape surrounding the refuge property is primarily agricultural. The 12 sites surveyed at Neal Smith NWR were representative of smaller reconstructions integrated into a larger restored landscape and hereafter will be referred to as integrated reconstructions.

The other 12 reconstructed sites and 12 prairie remnants were isolated areas of prairie in central Iowa (Fig. 1). Remnants averaged 11.53 (range = 6-25) hectares in size and the reconstructions had a mean of 17.29 (range = 6-33) hectares. We limited the size of prairies used in our study to avoid patch size effects. An ANOVA (Proc GLM, SAS Institute 2000) indicated no significant differences in area among the three prairie types (remnant, isolated reconstruction and integrated reconstruction, $df = 2$, $F = 1.54$, $p = 0.229$) and there was no correlation between butterfly richness ($r = -0.14$, $p = 0.428$) or abundance (-0.10, $p = 0.552$) and site area. Isolated reconstruction age ranged from 4 to 11 years old. The surrounding landscape for these sites was always non-prairie and usually agricultural (58 %, 14/24 sites) but sites could also be surrounded by forest (29 %, 7/24 sites) or manicured lawn (13 %, 3/24 sites).

All sites existed along a vegetative quality gradient ranging from a high to low level of plant diversity. Information on prairie quality was gleaned from interviewing the site managers and from plant species lists if available. A third of the remnant and isolated reconstructions and half of the integrated reconstruction sites were burned during the fall or spring preceding the surveys (14 burned, 22 unburned). A t-test between burned and unburned sites indicated that butterfly richness (but not abundance) was significantly different between the different management types ($df = 34$, $t = -2.13$, $p < 0.0402$). The effect of burning was compensated for in the data analysis.

Data Collection

Plants and butterflies were surveyed three times between May and August of 2003. The order the sites were surveyed in was kept constant through each of three rounds to maintain an evenly spaced time interval between visits. Butterfly and plant data for each site were collected within 0-2 days of each other. Butterfly activity was low during the first round of surveys, and on eleven of thirty-six sites we recorded no butterflies.

Butterflies were sampled using a transect method modified from Thomas (1983). Two 100x5 meter transects were laid out at each site at least 100 meters apart to minimize repeat sightings. The researcher walked the transect at a steady pace of approximately 10 meters/one minute for a total survey time of ten minutes. Every butterfly within a 5x5 meter visual field in front of the observer was identified (usually by sight) and recorded. Sampling time did not include capture and processing of individuals or recording (i.e., stopwatches were stopped for these activities). Specimens that could not be identified in the field were captured, and taken into the lab for identification. Surveys were only conducted on warm (not below 18 degrees Celsius), sunny (less than 60% cloud cover), and calm (sustained winds less than 17 kmph) days between 0930-1630 hrs. Data collected included the species name and the number of each species observed.

Vegetation sampling was conducted using 12 0.5 x 0.5 meter quadrats at each site. Six quadrats were located every 20 meters along each of the two butterfly transects. The data recorded included a description of the species present and a visual estimate of percent cover for each species as well as for duff and bare ground. It was not possible to identify all plants to the species level, so some (e.g., *Carex* sp.) were only identified to genus. Percent cover of each plant species was described as the proportion of the quadrat each species occupied in relation to all other live-plants. The % cover of duff and bare ground was the proportion each of these factors occupied in relation to each other and live-plant stem cover. The two observers standardized estimates of percent cover during the first round and plots were alternated between observers for the last two rounds in order to minimize observer bias. Number of ramets in bloom per species per quadrat was also noted to obtain a rough estimate of nectar availability.

Statistical Analysis

Differences between remnant and reconstructed prairies

The major components of the butterfly community examined were species richness, abundance, and composition. Species richness was defined as the total number of species observed at each site summed across the three rounds. Butterfly abundance was defined as the total number of individual butterflies observed summed across the two transects at each site and then averaged across three survey rounds. As a broad measurement of species composition, we used habitat affinities of butterflies described in the literature (Scott 1986, Opler & Krizek 1984, Ries, et al. 2001), to select a subset of 14 butterfly species (the most frequently recorded in their respective categories), which were split into habitat sensitive (7 species, HS species) and disturbance tolerant (7 species, DT species) (Table 1). HS butterflies are those species found primarily in grasslands with relatively low anthropogenic disturbance while DT species are common in many habitats regardless of disturbance level. A small number of observed butterflies (152 individuals) either did not fall into either category (i.e., woodland species) or were not one of the most abundant disturbance-tolerant species and therefore were not included in this analysis.

The three primary plant variables used to classify the vegetative quality of each site were plant diversity, the proportion of native plant species richness (% native), and the average coefficient of conservatism (average C) for each site. Plant diversity was determined by calculating Simpson's diversity index (Simpson 1949) for each round using percent cover values and then averaging the indices across the 3 rounds to achieve one diversity value per site. Percent native refers to the proportion of total plant richness on each site composed of native species. The average C was derived from a list of coefficients of conservatism assigned to each native prairie plant in Iowa. The coefficient is a value between 0 (disturbance tolerant) and 10 (disturbance intolerant) assigned to a plant based on its tolerance to disturbance. Summing and averaging the coefficients for a site provides a quantitative value indicative of the disturbance or degradation level of a site with pristine sites having a high average C and degraded sites having a low average C. Swink and Wilhelm (1994) devised the coefficient of conservatism system in an effort to standardize evaluations of prairie quality by placing the subjectivity of the process into the initial assignment of coefficients. We deviated from the recommended survey techniques (we did not survey the entire prairie, but focused on quadrats along transects), which resulted in lower than expected average C values, but survey techniques were consistent throughout and therefore so is the bias towards lower average C values.

Assignment of coefficients for Iowa was done by a group of prairie research professionals with knowledge of the prairie ecosystem in Iowa (Drobney et al. 1999). These three primary variables (plant diversity, % native, and average C) were chosen as the most likely plant variables used by reconstruction practitioners to evaluate the development of the plant community. Other vegetation characteristics examined to typify the relationship between the butterfly and plant communities at each site included: the proportion of native plant cover relative to total vegetation cover (% native cover), the proportion of forb cover relative to total vegetative cover (% forb), the proportion of potential host plant cover relative to total plant cover (% host), the proportion of duff cover relative to bare ground, dead vegetation cover (% duff), and the number of nectar- producing ramets in bloom (ramets).

A two-way analysis of variance (ANOVA) (Proc GLM; SAS Institute 2000) was performed to detect differences in butterfly richness and abundance on sites of different type (native, isolated reconstruction, Neal Smith NWR, and all reconstructions) and different management (burned or not burned during the spring or fall preceding the survey season). This ANOVA was repeated for the three main vegetative variables (plant diversity, % native, average C) and for richness and abundance of HS and DT butterflies. Contrast statements were used to compare differences between treatments.

Assessment of reconstructed prairies

Four analyses were used to determine whether butterflies were good indicators of the state of the plant community on reconstructed prairies. First, correlations were performed between butterfly richness and abundance and each of the three vegetative measures: plant diversity, % native, and average C. Second, vegetative rankings of the reconstructed prairies were determined by first calculating the average value of each variable (plant diversity, % native and average C) for all remnant (reference) sites. These mean values from the reference prairies were established as the "goal" value for each reconstructed site. Plant diversity, % native, and average C values for each reconstruction site were then divided by the goal value and these values were averaged to achieve one %-recovered value for each reconstruction (Table 2). The eight sites with the highest %-recovered values were labeled high quality, the middle eight were labeled medium quality and the lowest eight were labeled low quality. These quality categories were then used in a two-way ANOVA including burned vs. unburned treatments to test for differences in the butterfly community among these three quality types. Third, to examine whether the butterfly and plant communities exhibit similar trends on reconstructed prairies, %-recovered values were also calculated using butterfly richness and abundance (Table 2) and these values were used to perform a Spearman's rank correlation with the vegetative %-recovered values.

The fourth component of the assessment analysis was to examine species composition differences between different reconstruction quality levels and remnant prairies. The HS and DT butterfly designations were used to determine whether higher quality prairies supported higher levels of HS butterfly species. A two factor ANOVA on prairie quality and management was performed using HS and DT butterfly species richness and abundance. A further analysis of the butterfly community was performed using a non-metric multidimensional scaling (NMDS) technique. NMDS is a method used to plot sites using a community similarity measure (in this case Euclidean distance), which graphically represents which sites are more similar to each other in butterfly community composition. A two-dimensional solution was chosen for easy interpretation. The reduction in stress from a three-dimensional to a two-dimensional solution was small (stress for 2-dimensions = 17.512, stress for 3-dimenions = 12.874, reduction = 4.637) and a regression between ordination distances and distances in two-dimensional space was high ($R^2 = 0.819$). The NMDS plot was examined to determine whether sites of different quality were clustered and whether higher quality sites were more similar in butterfly community composition to remnant sites. All site scores as well as the mean site scores for each prairie type and quality are presented. The NMDS was performed using PC-ORD software (McCune & Mefford 1997).

Vegetative predictors of butterfly occurrence

The final analysis used was an all-subsets (C(p)) multivariate regression analysis (PROC REG; SAS Institute 2000) to determine which vegetation characters were the most predictive of butterfly richness and abundance. All plant variables listed above were examined for strong correlations ($r > 0.55$) and for those that were strongly correlated, one variable was dropped from the final regression analysis to avoid collinearity. The final list of independent variables used was: ramets, % duff, % native cover, area, average C, % host, and % forb. The standardized slope values of the variables in the best model were examined to determine whether the predictive direction was negative or positive. Regressions were conducted for all butterfly species on all sites as well as for remnant and reconstructed prairies separately to determine whether vegetative predictors were the same on the two types of sites.

Results

180 plant species and 37 butterfly species were identified over all sites during 2003. Butterfly individuals recorded totaled 1,314, which included 134 of the seven HS species and 1,028 of the seven DT species (Table 1). The prairie remnants supported 29-65 plant species and 6-11 butterfly species. Across all reconstructions plant species richness varied from 14-48 and butterfly species richness ranged between 2-14.

Differences between remnant and reconstructed prairies

Plant diversity and butterfly richness was significantly higher on remnant prairies than on the isolated reconstructions (Table 3). Plant diversity and butterfly richness were not however, significantly greater on remnants compared to integrated reconstructions. Average C and % native richness were significantly higher on remnants and isolated reconstructions than on integrated reconstructions (Table 3).

Butterfly abundance was highest on remnant prairies but differences among prairie types were not significant. HS butterfly richness was significantly higher on remnant prairies versus isolated reconstructions and HS abundance was significantly higher on remnants compared to integrated and isolated reconstructions. DT butterflies exhibited no significant difference in richness or abundance among different types of prairies (Table 3).

Assessment of reconstructed prairies

Butterfly richness was negatively correlated with average C on reconstructed prairies (Table 4). The negative relationship is unexpected, and the significance of the correlation disappears when remnant prairies are included in the analysis. This trend is primarily being driven by the integrated reconstructions which overall had a significantly lower average C but a higher level of butterfly richness than isolated reconstructions. There was no correlation between butterfly richness and abundance and plant diversity or % native plants.

There was no significant difference in butterfly richness or abundance among reconstructed prairies ranked as high, medium, and low quality based on vegetative %-recovered values (Table 3). However butterfly richness was higher on the higher quality prairies. The Spearman's rank correlation between %-recovered values using vegetation versus butterflies indicated there was no correlation in how these values ranked the reconstructed prairies ($r = -0.046$ $p = 0.831$).

On a broad level, butterfly species composition also did not differ between different quality reconstructions. Neither mean richness nor abundance of HS and DT species was significantly different between different quality reconstructions. Overall, prairies were very similar in butterfly community composition (fig. 2). The NMDS plots show no differentiating clusters of different prairie types or qualities and the mean site scores for prairie types and qualities are close together indicating high similarity in butterfly community composition (fig. 2).

Vegetative predictors of butterfly occurrence

The greatest predictor of butterfly richness on a site, when all sites were considered was the amount of nectar (in the form of number of ramets in bloom), the % cover of duff and average C. Analysis of the standardized slope indicates a positive relationship between butterfly richness and number of ramets and % duff but a negative relationship between butterfly richness and average C. The regression model including ramets, % duff and average C explained 37.6 % of the variation (Table 5).

There were no strong vegetative predictors of butterfly abundance when all sites and butterfly species were considered. The best model included # of ramets in bloom and % cover of duff but had an R^2 value of only 0.132 which was not significantly different from zero ($F = 2.51$, $p = 0.097$). In addition, butterfly abundance was not highly correlated with any of the vegetative components used in producing the regression model (Table 5).

The best predictor of butterfly richness on remnant prairies was % cover of duff but this model did not explain a significant amount of the variation ($F = 1.41$ $p = 0.263$) (Table 5). The relationship between % cover of duff and butterfly richness was positive. Butterfly abundance on remnant prairies was strongly explained by a model including ramets in bloom, % cover of duff, and % cover of native species. Butterfly abundance was positively correlated with each of the plant variables in the top model (Table 5).

Ramets in bloom, % cover of duff, and average C were included in the best model for butterfly richness on reconstructed prairies. As in the best model for all prairies butterfly richness is positively correlated with # of ramets and % cover of duff but negatively correlated with average C. Percent cover of forbs was the only variable in the best model for butterfly abundance but it did not explain a significant amount of variation ($F = 0.78$, $p = 0.387$)(Table 5).

Discussion

The importance of remnant prairie habitat

As hypothesized, remnant prairies supported higher numbers of butterfly species and higher values for all of the primary plant variables (diversity, % native, and average C) than reconstructed prairies. This trend has been found for a number of organisms in other grassland studies (Panzer et al. 1995; Wheater & Cullen 1997; Brand & Dunn 1998; Bomar 2001) but was not universal (Bisevac & Majer 1999). This confirmed that the remnant prairies used in the study were appropriate references.

In addition to validating the reference prairies, the analysis of the data comparing types of prairies revealed two interesting trends. First, the integrated reconstructions did not differ significantly in butterfly richness from remnant prairies, placing them in an intermediate position between remnant and isolated reconstructions. Integrated reconstructions supported higher plant diversity than isolated reconstructions, but ranked lowest in % native and average C, so average vegetation quality was not superior to isolated reconstructions. While many other factors may be involved in influencing higher butterfly richness at Neal Smith NWR (integrated reconstructions), a plausible explanation is the clustered nature of the restorations, the landscape-scale of the project, and its integration of small patches of remnant vegetation, thus providing adjacent sources for colonization and a larger area of suitable habitat. The benefit of larger area and less isolation in promoting species richness is derived from island biogeography theory (MacArthur & Wilson 1963) and community assembly rules (Keddy 1999). Fry and Main (1993) advocate the consideration of landscape context and the potential for colonization and movement in reconstructing fragmented ecosystems. Steffan-Dewenter and Tscharntke (2002) found that butterfly species richness overall and the proportion of monophagous species was higher on larger grassland fragments. In montane wetlands, Wettstein and Schmid (1999) reported that butterfly richness, especially of wetland specialists, was positively related to habitat area and the amount of suitable habitat in a 4 km radius of the study site.

The second trend to emerge in the analysis of prairie type was the significantly greater richness and abundance of habitat sensitive butterfly species on remnant prairies (DT species exhibited no difference among prairie types). In addition, while the difference is significant for HS species abundance, integrated reconstructions are again in the intermediate position, further supporting Wettstein and Schmid (1999) and Steffan-Dewenter and Tscharntke (2002). Kitahara and Fujii (1994) examined specialist vs. generalist butterfly species richness along an anthropogenic disturbance gradient and found that specialists differed among treatments while the number of generalist species did not. Panzer et al. (1995) designated a list of arthropods labeled as remnant-dependent based on the degree of their reliance on remnant prairies.

The preference of habitat sensitive butterfly species for remnant prairie suggests that these prairies, including degraded remnants, possibly experience fewer disturbances and are refuges (and potential sources) for many sensitive butterfly species. The trend towards higher numbers of habitat sensitive butterflies on integrated reconstructions when compared to isolated reconstructions implies the utility of integrating reconstructions with remnants to encourage these butterfly species.

Assessment of vegetative quality on reconstructed prairies

Our results suggest that the adult butterfly community is a limited indicator of the vegetative quality of a reconstruction (based on plant diversity, %native plants and average C). Abundance and richness of butterflies was higher on reconstructed prairies with high vegetative quality but it was not enough to significantly distinguish between quality categories. Several recent studies examining population and behavior of a single butterfly species have found that habitat quality is an important factor in determining population dynamics (abundance) and behavior (i.e. number and location of eggs) (Dennis & Eales 1999; Fleishman et al. 2002; Fownes & Roland 2002; Matter & Roland 2002).

However, it may be more difficult to pinpoint trends related to habitat quality when examining the full butterfly community, which contains many species exhibiting different habitat requirements or tolerances. In addition we did not record many habitat-sensitive prairie butterflies on our study sites. Even the less impacted remnant prairies are heavily degraded and may only support a truncated butterfly species assemblage which excludes many of the prairie specialists. The NMDS results, which indicate little difference in species composition between remnant and reconstructed prairies, support the theory of a homogenized, primarily habitat generalist butterfly community occupying central Iowa prairies. A generalized butterfly community, such as that found in Central Iowa may be incapable of reflecting a difference in prairie vegetative quality.

The absence of a correlation between butterfly richness and abundance and two of the primary vegetative variables (plant diversity, % native plant richness) is not surprising. The association between butterflies and the vegetative community led us to predict that butterflies would be sensitive to differences in these vegetative parameters. However, other studies have shown butterflies to be poor indicators of vegetative diversity (Kremen 1992; Holl 1996) and butterfly richness may not respond negatively to exotic plant cover (Simonson et al. 2001). There are several other variables that we did not measure for which the butterfly community may exhibit a stronger connection: landscape and topography features (Kremen 1992), vegetation structure (Soderstrom et al. 2001), age of reconstruction (Holl 1996; Brand and Dunn1998; Bisevac and Majer 1999) and as suggested by the integrated reconstruction data, area and isolation. These and other possible variables affecting the butterfly community dynamics may obscure the relationship with habitat quality.

In addition, the negative correlation between butterfly richness and average C is unexpected but it may have a simple explanation. The plants that are included in the seeding mix are principally what determine average C on reconstructions. Butterflies, however, are mobile and their presence on a site is more closely a function of their ability to colonize. As mentioned above the integrated reconstructions, which in this case had a significantly lower average C than the remnants and isolated reconstructions, encourage the colonization of butterflies by being large and close to sources of butterfly colonization (small prairie remnants). We suggest that the negative relationship between butterfly richness and average C is being driven by the integrated reconstructions, which have encouraged faster development of the mobile butterfly community but were not planted with a high density of conservative prairie plants. Therefore the relationship is indirect and related exclusively to our study sites.

The focus, of this study and others, on the adult stage of the butterfly life cycle may also explain the unexpected weak response of butterflies to habitat quality. Most adult butterflies are fairly vagile and may utilize many habitat patches for a short period of time and not be resident (reproductive) there. This study and several others have found that nectar resources are of primary importance in determining butterfly occurrence (Holl 1995; Loertscher et al. 1995; Matter & Roland 2002) and while correlations between host plant availability and butterfly occurrence has been established (Thomas & Singer 1987; Clausen et al. 2001; Fleishman et al. 2002), with the exception of Clausen et al. (2001), these studies focused on a single host-restricted species. We suggest that host plant availability is important but that it may be important to adult butterflies for only a short period of the flight time and the relationship may be obscured by looking at many different butterflies, which associate with several different host plants. An examination of all butterfly life stages may reveal a stronger connection to plant diversity and % native plant richness and hence a stronger indication of the vegetative quality of the restoration.

One trend that became clear in our results was that reconstruction management, in this case prescribed burning, played a role in butterfly community dynamics. The strong response of butterfly richness and abundance to a prairie's prescribed burn status, in conjunction with the importance of % cover of duff as a predictor variable may have obscured a butterfly response to vegetative composition.

Management of Reconstructions

Discussions of prescribed burning and its effect on arthropods appears often in the literature (Warren et al. 1987; Reed 1997). For butterflies it has generally been shown that frequent burning has a detrimental effect (Dana 1991; Swengel 1996; Schultz & Crone 1998) and this effect is strongest in the short-term (the growing season following a fire) (Swengel 1996; Greenslade 1997; Siemann et al. 1997). The long-term effects of fire are probably beneficial (Siemann et al. 1997; Schultz & Crone 1998) but communities must be allowed time to recover.

Results from our study suggest that fires, by removing the duff layer, in the season following the burn may inhibit butterfly use of those prairies. Some butterfly species use dead vegetation as oviposition sites (i.e., *Speyeria idalia*, Kopper et al. 2000) and several species over-winter as larvae or eggs in the duff layer (Scott 1986). By removing the duff layer and causing mortality of over-wintering larvae (Dana 1991), the intensive prescribed burning of reconstructed prairies may be affecting the butterfly community with the same strength as the composition of the vegetative community.

Conclusions

Butterflies are only limited indicators of vegetative development and success on reconstructed prairies. Their level of adult mobility and response to management may confound their indicator potential. Examination of all stages in the butterfly life cycle may strengthen the observed response to vegetation but would remove the advantage associated with the sampling of adult butterflies. In addition, the butterfly species, which may be most sensitive to vegetation quality differences on prairies may be missing from the species assemblage. The differences in species richness and abundance on remnant versus reconstructed prairies indicate that most prairie reconstructions in central Iowa have not reached the highest level of butterfly community diversity.

There are a number of recommendations we would suggest for reconstruction projects to foster the butterfly community. Larger reconstructions that incorporate existing remnants will encourage colonization and support greater species richness. When planting prescriptions are designed, plants that produce nectar and that will bloom in succession to cover the entire flight season should be incorporated. Finally, conservative management with respect to prescribed burning should be favored.

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Tables and Figures

Table 1. A subset of fourteen butterfly species was chosen and split into habitat-sensitive species (HS species) and disturbance-tolerant species (DT species). Habitat sensitive butterflies were defined as those species found primarily in areas of relatively low anthropogenically disturbed grassland while disturbance tolerant species were common in many habitats regardless of disturbance level. These designations were made by using habitat characterizations from the literature (Opler & Krizek 1984; Scott 1986; Ries et al. 2001). 152 recorded individuals were not included in this analysis because they either did not fit in one of the categories (i.e., woodland species) or they were disturbance-tolerant species that did not occur in great enough numbers.

Habitat-sensitive Species			*Disturbance-tolerant Species*		
Common Name	*Latin Name*	*N*	*Common Name*	*Latin Name*	*N*
Common Wood Nymph	*Cercyonis pegala*	52	Eastern-tailed Blue	*Everes comyntas*	559
Regal Fritillary	*Speyeria idalia*	50	Orange Sulphur	*Colias eurytheme*	151
Gray Copper	*Lycaena dione*	15	Clouded Sulphur	*Colias philodice*	143
Meadow Fritillary	*Boloria bellona*	12	Pearl Crescent	*Phyciodes tharos*	68
Delaware Skipper	*Anatrytone logan*	2	Monarch	*Danaus plexippus*	64
Silvery Checkerspot	*Chlosyne nycteis*	2	Cabbage White	*Pieris rapae*	25
Bronze Copper	*Lycaena hyllus*	1	Black Swallowtail	*Papilio polyxenes*	18
Total Number HS Individuals Recorded		**134**	**Total Number DT Individuals Recorded**		**1028**
Proportion of Total Butterflies Recorded		10%	Proportion of total Butterflies Recorded		78%

Table 2. Percent recovered (%-recovered) values for vegetation and butterflies on all reconstructed prairies. Vegetative rankings of the reconstructed prairies were determined by first calculating the average value of each variable (plant diversity, % native, average C) for all remnant (reference) sites (in table, reference mean). These mean values from the reference prairies were established as the "goal" value for each reconstructed site. Plant diversity, % native, and average C values for each reconstruction site were divided by the goal value for each variable and then averaged to obtain a %-recovered value (all values listed in the column below reference mean are a proportion of the reference mean for each reconstructed site). The eight sites with the highest %-recovered values were labeled high quality, the middle eight were labeled medium quality, and the lowest eight were labeled low quality. Butterfly %-recovered values and rankings of prairies were determined in the same manner as the vegetation but using butterfly richness and abundance values.

	Vegetation					Butterflies			
Reconstructed Sites	*Diversity*	*% Native*	*Avg. C*	*MEAN %- recovered*	*QUALITY LEVEL*	*Richness*	*Abundance*	*MEAN %-recovered*	*QUALITY LEVEL*
Reference Mean	**9.88**	**0.795**	**3.95**			**9.17**	**13.83**		
NSNWR1	0.143	0.780	0.608	**0.510**	Low	0.981	0.458	**0.720**	Medium
Jester Park	0.262	0.881	0.681	**0.608**	Low	0.982	1.108	**1.045**	High
NSNWR26	0.345	0.792	0.747	**0.628**	Low	0.218	0.458	**0.338**	Low
NSNWR70	0.432	0.704	0.760	**0.632**	Low	0.982	1.542	**1.045**	High
NSNWR25	0.431	0.767	0.760	**0.653**	Low	1.091	0.699	**0.895**	Medium
McFarland	0.498	0.918	0.808	**0.741**	Low	0.436	0.096	**0.266**	Low
Colo Bogs	0.328	0.780	1.140	**0.749**	Low	0.545	0.530	**0.538**	Medium
NSNWR17	0.653	0.780	0.833	**0.755**	Low	0.655	0.313	**0.484**	Medium
Meetz	0.541	0.918	0.823	**0.761**	Medium	0.545	0.651	**0.598**	Medium
Prairie Flower	0.477	1.044	0.803	**0.775**	Medium	1.200	1.205	**1.203**	High
Big Creek	0.344	1.094	0.963	**0.800**	Medium	0.764	0.385	**0.575**	Medium
NSNWR23	0.764	0.906	0.788	**0.819**	Medium	0.655	0.193	**0.424**	Low
Richard's Marsh	0.617	0.969	0.894	**0.827**	Medium	0.436	0.193	**0.315**	Low
NSNWR10	0.998	0.767	0.826	**0.864**	Medium	0.873	0.554	**0.714**	Medium
NSNWR21	1.029	0.855	0.724	**0.870**	Medium	1.418	0.867	**1.143**	High
Grimes Farm	0.777	0.981	0.940	**0.899**	Medium	0.218	0.410	**0.314**	Low
NSNWR19	1.087	0.918	0.717	**0.907**	High	1.200	1.012	**1.011**	High
Briggs Woods	0.644	1.031	1.056	**0.910**	High	0.327	0.145	**0.236**	Low
NSNWR42	0.905	1.006	0.851	**0.921**	High	0.764	0.265	**0.515**	Medium
Hanging Rock	1.268	0.830	0.907	**1.002**	High	1.527	1.567	**1.547**	High
Stargrass	0.917	1.006	1.109	**1.011**	High	0.436	0.988	**0.712**	Medium
Prairie Creek	1.134	1.006	1.006	**1.049**	High	0.873	3.205	**2.039**	High
NSNWR44	1.312	0.981	0.917	**1.070**	High	0.982	0.844	**0.913**	High
NSNWR31	1.512	0.843	0.866	**1.074**	High	0.655	0.265	**0.460**	Low

Table 3. Least square means for all butterfly, habitat-sensitive (HS), and disturbance-tolerant (DT) species richness and abundance as well as plant diversity[1], % native plant richness (% native), and average coefficient of conservatism (Avg. C). LSMean estimates of butterfly and vegetation variables for restored/native and management from a two factor ANOVA with factors type and management. LSMeans of butterfly richness and abundance for quality from a two factor ANOVA with factors, quality and management. Numbers in parentheses following LSmeans are standard errors. Different lettered subscripts indicate significant differences. * = significance at the p >.05 level, ** = significance at the p > 0.01 level.

		Butterfly						*Vegetation*		
Types of sites	*N*	*Richness*	*Abundance*	*HS Species Richness*	*HS Species Abundance*	*DT Species Richness*	*DT Species Abundance*	*Diversity*	*% Native*	*Avg. C*
Restored/ Native[2]										
Remnant	12	9.13(0.79)[a]	13.48(2.66)[a]	1.50(0.30)[a]	1.92(0.386)[a]	4.88(0.37)[a]	9.94(2.68)[a]	10.03(1.06)[a]	0.80(0.02)[a]	3.86(0.16)[a]
Isolated	12	6.00(0.79)[b*]	11.73(2.66)[a]	0.50(0.30)[b*]	0.49(0.386)[b**]	4.38(0.37)[a]	11.31(2.68)[a]	6.63(1.06)[b*]	0.76(0.02)[a]	3.68(0.16)[a]
NSNWR	12	8.00(0.75)[ab]	8.61(2.61)[a]	1.08(0.28)[ab]	0.67(0.364)[b*]	4.83(0.35)[a]	7.67(2.53)[a]	7.91(1.00)[ab]	0.67(0.02)[b**]	3.09(0.15)[b*]
Quality Level										
High	8	8.33(1.14)[a]	14.76(3.54)[a]	0.63(0.35)[a]	0.21(0.30)[a]	4.93(0.53)[a]	13.46(3.47)[a]	NA	NA	NA
Medium	8	6.60(1.14)[a]	7.12(3.54)[a]	0.73(0.35)[a]	0.58(0.30)[a]	4.50(0.53)[a]	6.22(3.47)[a]	NA	NA	NA
Low	8	5.83(1.27)[a]	7.78(3.96)[a]	0.75(0.39)[a]	0.72(0.33)[a]	4.08(0.59)[a]	6.44(3.88)[a]	NA	NA	NA
Manage-ment[3]										
Burned	14	6.67(0.71)[a]	10.21(2.44)[a]	0.64(0.27)[a]	0.14(0.28)[a]	4.02(0.33)[a]	7.13(3.22)[a]	8.93(0.94)[a]	0.76(0.02)[a]	3.54(0.14)[a]
Unburned	22	8.75(0.56)[b*]	12.33(1.94)[a]	1.42(0.21)[b*]	0.87(0.23)[b**]	5.36(0.26)[b**]	10.28(2.65)[a]	7.46(0.74)[a]	0.72(0.02)[a]	3.55(0.11)[a]

[1]Plant diversity calculated using the Simpson index (Simpson 1949).
[2]Isolated = isolated reconstructed prairie and NSNWR = Neal Smith NWR reconstructed prairie.
[3]Management designation based on whether a site was burned or not in the spring or fall prior to data collection.

Table 4. Correlations between the primary vegetation variables; plant diversity, % native plant richness (% Native), and average coefficient of conservatism (Average C); and several butterfly variables ; butterfly richness and abundance, habitat-sensitive (HS Species) butterfly species richness and abundance, and disturbance tolerant (DT Species) butterfly species richness and abundance. Numbers presented are Pearson correlation coefficients for the above variables for all sites (including remnant prairies) and just reconstructions. * = significant at the p > 0.05 level.

		Vegetative Variables		
Butterfly Variables	*N*	*Plant Diversity*	*% Native*	*Average C*
All Sites				
Richness	36	0.230	0.024	-0.085
Abundance	36	0.129	0.189	0.199
HS Species Richness	36	0.050	-0.004	0.075
HS Species Abundance	36	0.074	0.120	0.356*
DT Species Richness	36	0.134	-0.075	-0.124
DT Species Abundance	36	0.141	0.137	0.139
Reconstructions				
Richness	24	0.257	-0.201	-0.411*
Abundance	24	0.251	0.037	0.089
HS Species Richness	24	-0.050	-0.307	-0.349
HS Species Abundance	24	-0.286	-0.312	-0.146
DT Species Richness	24	0.148	-0.179	-0.314
DT Species Abundance	24	0.305	0.033	0.120

Table 5. The best predictors of butterfly richness and abundance on all prairie sites as well as on native and reconstructed prairies separately. Models were calculated using an all-subsets multivariate regression with the following variables: % native plant species cover, % native plant species richness, number of ramets in bloom, % cover of duff, % forb cover, % host plant cover, average coefficient of conservatism (Avg. C), and area. * = R^2 is significantly different from zero at $p > 0.01$ level.

Butterfly Variables	*N*	*C(p)*	R^2	*Variables in Best Model*	*Standardized B (slope)*
All Sites					
Richness	36	1.31	0.38*	Ramets	0.590
				% Duff	0.454
				Avg. C	-0.283
Abundance	36	0.30	0.13	Ramets	0.274
				% Duff	0.324
Reconstructions					
Richness	24	1.76	0.45*	Ramets	0.531
				% Duff	0.452
				Avg. C	-0.366
Abundance	24	-0.17	0.03	% Forb	0.185
Remnants					
Richness	12	-0.26	0.12	% Duff	0.352
Abundance	12	2.13	0.71*	% Native Cover	0.685
				Ramets	0.523
				% Duff	0.882

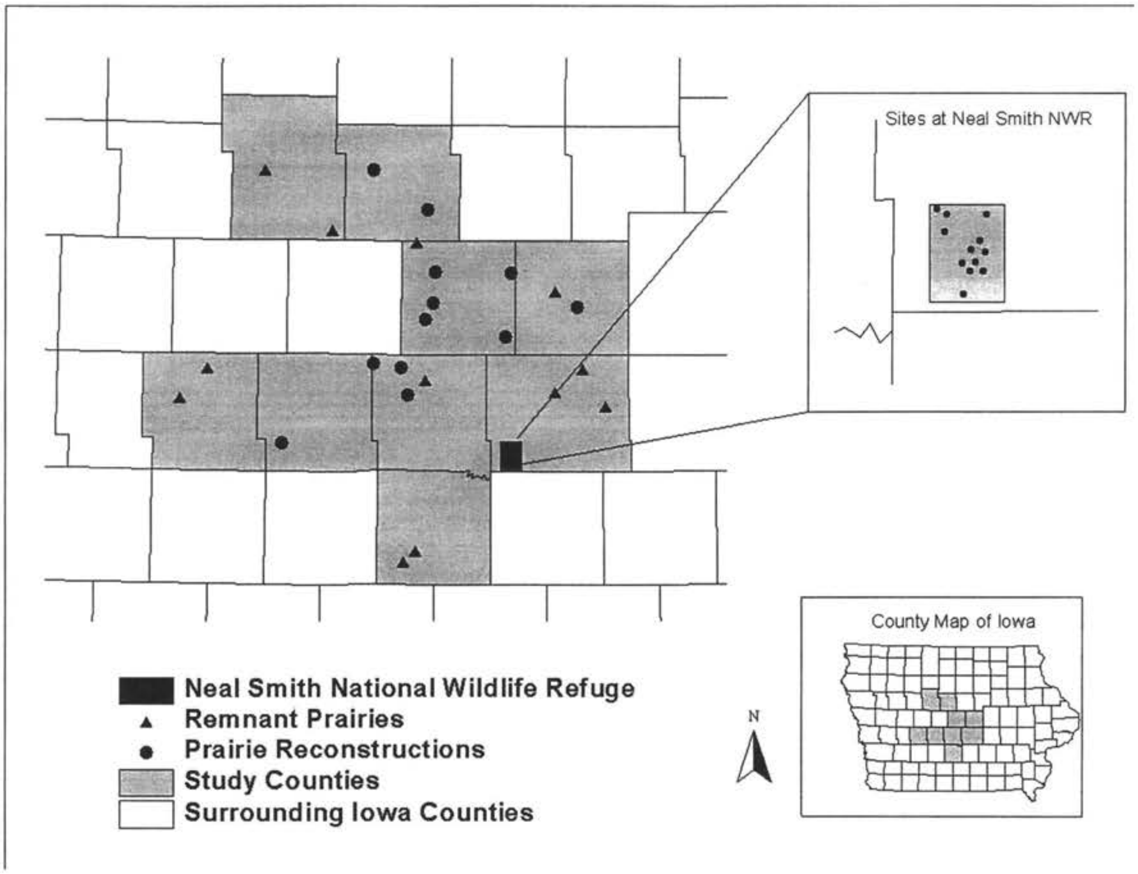
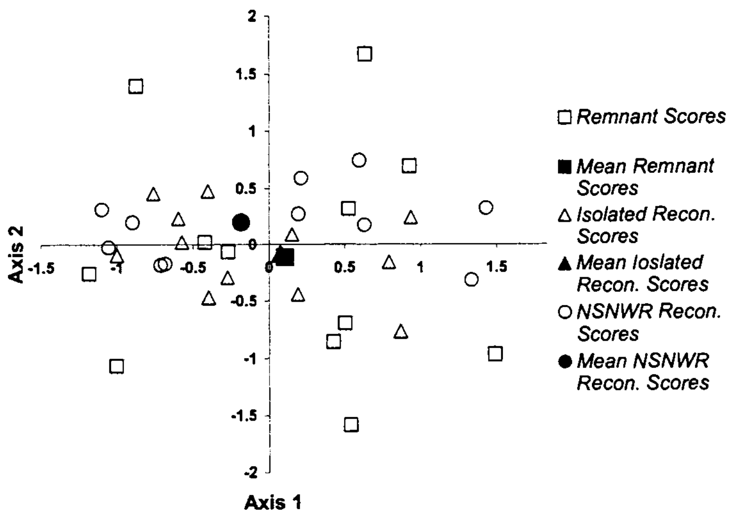


Figure 1. Map of study areas showing approximate locations of reconstructed and remnant prairies in Central Iowa, U.S.A. Insets show the context of the sites within Iowa and a closer view of the twelve reconstructed prairie sites at Neal Smith National Wildlife Refuge.

A.



B.

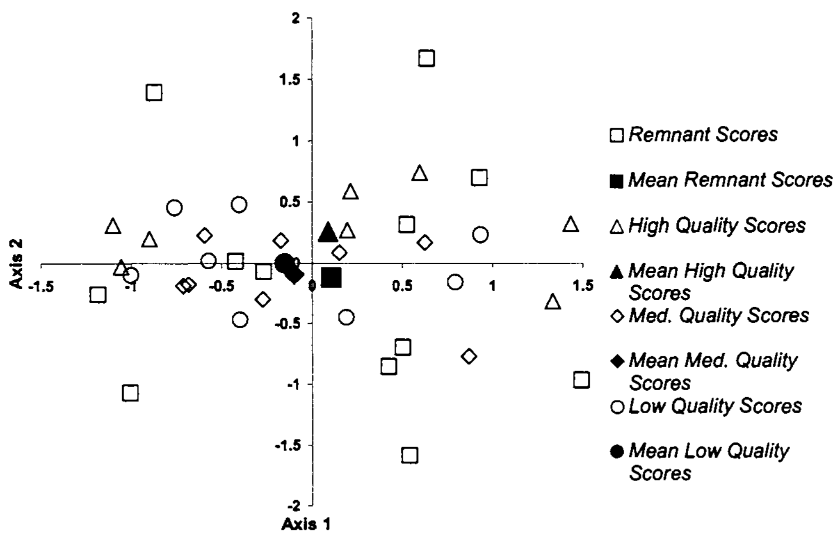


Figure 2. Plots of butterfly community similarity using non-metric multidimensional scaling (similarity measure = Euclidean Distance). Distance between points represents the degree of similarity (i.e., the closer the points the greater similarity). Butterfly community composition does not strongly differentiate prairies of different type or quality. A) Plot of butterfly community similarity between different types of prairies. Data for each site as well as the mean similarity for each type are presented. B) Plot of butterfly community similarity between remnant prairies and reconstructed prairies of differing vegetative quality (High, Medium, and Low). Data for each site as well as the mean similarity for remnant and each quality category are presented.

The reintroduction of a declining insect associated with an endangered ecosystem: A case study with the Regal Fritillary (*Speyeria idalia*) in a reconstructed prairie in Central Iowa

A paper to be submitted to *Restoration Ecology*

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Abstract: *The decline of several prairie endemic butterfly species in the Midwestern United States has been well documented. The diminishing numbers of these species is strongly associated with the destruction and fragmentation of their prairie habitat. One conservation strategy that can be used to compensate for both the loss of prairie and its endemic insect fauna is the reintroduction of rare butterfly species into reconstructed (from bare ground) prairie areas. In this paper we examine our efforts to reintroduce* Speyeria idalia, *a declining prairie endemic butterfly, to a 1,250-hectare reconstructed prairie at Neal Smith National Wildlife Refuge, Jasper County, IA. In 1998 and 1999 we established 1,980 individuals of* S. idalia's *host plant,* Viola pedatifida, *in four planting units at the refuge. Captive rearing of* S. idalia *larvae was unsuccessful, thus we decided to move gravid females from an area that supported a large population of* S. idalia *and that was located within the 38 county local ecotype zone of the refuge. Gravid females were introduced into mesh cages located on violet plots at the refuge in 2000 (4 individuals) and 2001 (3 individuals). Surveys for larvae and adults were conducted in 2001 and 2002. No larvae or adults were observed in 2001. In 2002, no larvae were detected but adult* S. idalia *appeared during surveys in early July and persisted through late August. However, surveys conducted on several prairies in the vicinity of the refuge indicated that* S. idalia *were experiencing a high population year and that long-distance dispersals were likely. In addition, the presence of female* S. idalia *was never confirmed on refuge property. A lack of detailed knowledge of* S. idalia *population dynamics and the difficulty in detecting and catching females in source areas provided two significant obstacles for our introduction project and the project will need to be long-term. It does appear, however, that in the case of* S. idalia, *reconstructed prairies may serve as adequate habitat.*

Introduction

Prairie is one of the most human impacted ecosystems in North America. For example, the state of Iowa, USA, only supports 0.1% of a historical 28.8 to 31.3 million acres of prairie because of extensive conversion of land to agricultural practices (Smith 1998). The prairie ecosystem has become endangered with only small isolated areas of native prairie remaining (Packard & Mutel 1997; Smith 1998).

A consequence of prairie loss is the endangerment of prairie-associated organisms. An example of this synergistic response of prairie organisms to prairie loss is the decline of many prairie endemic butterflies in the Midwestern U.S., where prairie fragmentation and destruction has been severe. In Iowa, Schlicht and Orwig (1998) estimated nine prairie endemic butterflies to be endangered (existing on fewer than 20 sites) and 11 more to be threatened (existing on 21-100 sites). An oft-cited cause of butterfly population decline and loss is the destruction and fragmentation of their habitat (Pullin 1996; Schlicht & Orwig 1998).

The importance of prairie endemic butterflies to conservation is two-fold. First, butterflies play an essential role in ecosystem functioning as pollinators, herbivores, and as a food source for other organisms (Martin et al. 1951; Scott 1986; Hendrix & Kyhl 2000). Second, butterflies may serve as umbrella species for the endangered prairie ecosystem. Launer and Murphy (1994) found that if all grassland sites that supported *Euphydryas editha bayensis* (an endangered butterfly in California) populations were protected, 98% of the native spring flowering plant species would also be protected. In addition, the popularity and "charisma" of butterflies may encourage greater support for conservation efforts and as a consequence essential prairie habitat may be saved.

One strategy for conserving declining butterfly species is the preservation and enhancement of existing butterfly habitat (Launer & Murphy 1994; Smallidge & Leopold 1997; Marttila et al. 2000; O'Dwyer & Attiwill 2000; Schultz 2001). Efforts at restoring rare butterfly habitat are often successful in encouraging population recovery (Marttila et al. 2000; Schultz 2001) but restoration of existing natural areas does not always alleviate the problem of habitat fragmentation. Many endangered butterflies exist in relatively small areas of suitable habitat isolated in a much larger matrix of unsuitable habitat (Pullin 1996; Marttila et al. 1997; O'Dwyer & Attiwill 2000). The connectivity and size of habitat may be as important as habitat quality (Moilanen & Hanski 1998; Dennis & Eales 1999).

Another technique used to enhance rare butterfly populations is reintroducing species into a formerly inhabited area. Most reintroduction projects involve introducing the butterfly into a restored area of formerly degraded habitat (Dempster & Hall 1980; Williams 1995; Pullin 1996; Marttila et al. 1997; Witkowski et al. 1997; Wynhoff 1998; Barascud et al. 1999). Another possibility is to reintroduce butterfly species into a reconstructed area of habitat, which is defined as the planting of natural vegetation (in this case, prairie) into plowed (bare) ground (Packard & Mutel 1997; Smith 1998). Reconstruction projects have an advantage over restoration of existed degraded habitat by providing more possibilities for increasing the amount and connectivity of habitat in a landscape. Here, we investigate the reintroduction of a prairie endemic butterfly, *Speyeria idalia*, into a reconstructed prairie.

Currently, it is unclear whether a habitat-sensitive butterfly once introduced will be able to thrive in a reconstructed habitat (Panzer et al.1995). Few studies have been published that detail reintroduction efforts for butterflies (Dempster & Hall 1980; Pullin 1996; Witkowski et al. 1997; Marttila et al. 1997; Wynhoff 1998) and to our knowledge there are no published accounts of butterfly reintroduction projects that have explored introducing individuals into reconstructed habitat. Many problems are associated with reintroducing butterflies because of their connection to the vegetation community, strict habitat requirements and complex life histories, thus published reports of reintroduction success and failure is crucial.

In this study, we use the prairie endemic butterfly, *Speyeria idalia* (regal fritillary), to assess the hosting potential of reconstructed prairies to rare butterfly species. *S. idalia* is classified as threatened in Iowa by Schlicht and Orwig (1998) and has experienced a severe contraction of its entire distributional range (Hovanitz 1963; Opler & Krizek 1984; Scott 1986; Wagner et. al 1997; Zercher 2001). It has restricted host plant requirements (*Viola* sp.) and is usually associated with large areas of native prairie or grassland that support its restricted host plant (Opler & Krizek 1984; Scott 1986). *S. idalia* is an ideal candidate for reintroduction, because while it is declining, it is still abundant enough in some areas of Iowa to permit flexibility in moving individuals. In addition, it is a large, showy butterfly, capable of exciting public interest and support for its preservation.

Here we detail efforts to reintroduce *S. idalia* and its host plant (*Viola pedatifida*) to a large prairie reconstruction in Central Iowa, USA. Details of the first five years (1998-2002) of this reintroduction project are presented with an emphasis on the obstacles encountered and lessons learned.

Life History and Status of *Speyeria idalia*

Life History

Speyeria idalia is a member of the family Nymphalidae (brush-footed butterflies). It is a large, distinctive butterfly, which portrays obvious sexual dimorphism. *S. idalia* are univoltine and females are especially long-lived. Males emerge in mid-June approximately two weeks before the females, which emerge in early July. Females mate immediately after emergence but enter a reproductive diapause until mid August/early September. Once oviposition begins the female deposits up to 2500 eggs (Wagner et. al 1997) in the vicinity of (but not on) the host plant (*Viola* sp.) (Kopper et al. 2000). Larvae hatch in about one month, eat the chorion of their egg and go into diapause for the winter (Kopper et. al 2000). They become active again in early May and must search for a host plant to feed on.

Habitat Requirements

Speyeria idalia are most often associated with prairie, both tallgrass and midgrass, but in the eastern part of their range they will be found in various open grassy situations. Because they prefer wetter grasslands (Scott 1986, Opler & Krizek 1984, Wagner et. al 1997), in Iowa and elsewhere, they have primarily been found in prairies with some topographical relief, which provides moist areas in the lowlands and dryer areas for the host plant on the uplands (Swengel 1997; Zercher 2001; personal observation). *S. idalia* seems to be restricted in its habitat requirements by the availability of its host plant. The larvae feed on *Viola pedatifida* (Blue prairie violet), *V. pedata* (Bird's-foot violet), *V. lanceolata* (Lance-leafed violet), *V. frimbriatula* (Ovate-leaved violet), *V. nuttallii* (Nuttall's violet), and *Viola sagittata* (Arrowleaf violet) (Wagner et. al 1997, Debinski & Kelly 1998, Opler & Krizek 1984). *V. pedatifida* and *V. pedata*, which are the most commonly used host plants in the Midwest, average about six inches in height, bloom in May and prefer well-drained, dryer soil in prairie habitat (Shirley 1994). Adult *S. idalia* use thistles (*Cirsium* sp.) and milkweeds (*Asclepias* sp.) as primary nectar sources. Because of *S. idalia*'s late flight time (into September), a continuous supply of nectar into the late summer may be limiting.

Another apparent requirement is an open grassy area of large size. In Iowa, the largest populations of *S. idalia* are found exclusively on prairies exceeding 67 hectares (Debinski & Kelly 1998; personal observation). Managers at the Fort Indiantown Gap National Guard Training Center in Pennsylvania have determined after several years of research that 104 hectares is the minimum required area to sustain a viable population (Zercher 2001).

Status

The historic range of *S. idalia* extended from North Dakota south to Colorado and east to Virginia and Maine (Scott 1986; Opler & Krizek 1963; Hovanitz 1963), but only two populations remain east of Illinois (Swengel 1993;Wagner et. al 1997; Zercher 2001). In many of the states where they are still present, *S. idalia* occurrence is local and rare (Debinski & Kelley 1998; Zercher 2001).

The last known populations in the eastern part of the range are in the Appalachian Mountains of Virginia and at Fort Indiantown Gap National Guard Training Center. The disappearance of the regal fritillary in the east has occurred approximately in the last 60 years (Barton 1995; Gochfeld & Burger 1997; Wagner et al. 1997). Out of 52 Iowa prairies surveyed in 1995, only 11 were found to host *S. idalia*. Further, only 7 of these 11 prairies supported *S. idalia* populations of over 50 individuals (Debinski & Kelly 1998).

Methods

Reintroduction Area

Neal Smith NWR (formerly known as Walnut Creek National Wildlife Refuge) in Jasper County, IA is a large-scale prairie reconstruction established in 1991 (Drobney 1994)(Fig. 1). It encompasses approximately 1,250 hectares of reconstructed prairie on a total 2,083 hectares of refuge property. A majority of the refuge property prior to prairie vegetation establishment was in agricultural production, though a few small, scattered remnant prairies were also present. Surveys prior to the refuge establishment reported 51 species of butterflies but no *S. idalia* (Klaas & Bishop 1995). There are a few native prairie sites within a 15-mile radius of the refuge that support small *S. idalia* populations (pers. obs.).

Host Plant Establishment

In 1998 and 1999, a total of 1,980 local ecotype *Viola pedatifida* (blue prairie violet) plants were planted at Neal Smith NWR. Violets were planted in four planting units representing four treatments: grazed (within an enclosure housing bison) (1999), burned (1998), unburned sparse planting (1999), and unburned dense planting (1998). The violet plot treatments have since been compromised because all plots but the unburned dense planting were burned in 2002. Within each of these planting units were five plots each containing 99 violet plants, planted one meter apart in a 9 X 11 plant grid (total plots = 20). All planting units where violets have been established were located in the interior of the refuge (Fig. 1B).

Violet plots have been surveyed for survivorship each spring since establishment. The location of each plant in the grid is marked with a flag so that the presence or absence of that plant can be determined each year. Violet survival data is presented for 2002.

Speyeria idalia Introduction

Many butterfly reintroduction projects involve releasing larvae or adults that have been bred in the lab (Hammond & McCorkle 1991; Witkowski et al. 1997; Nicholls & Pullin 2000). Lab rearing of *S. idalia* has proved extremely difficult (Wagner et al. 1997; personal observation) therefore it was determined that for the release at Neal Smith NWR we would introduce wild-caught gravid females. Wynhoff (1998) and Marttila et al. (1997) had previously introduced wild-caught adult butterflies with some success, while Williams (1995) introduced wild harvested eggs, which was not successful.

The source population for *S. idalia* females was located at Ringgold Wildlife Area, a 500-hectare prairie in southern Iowa (Fig. 1A). It was within the local ecotype region for Neal Smith NWR and Debinski and Kelly (1998) had determined the population at Ringgold to be relatively large. *S. idalia* surveys of Ringgold were performed in 2000-2002 in order to confirm the presence of a thriving population. Extensive surveys of three high population areas at Ringgold were completed five times between 7-4-01 and 7-29-01 and individuals caught were marked with a felt tip pen. Fifty-six individual *S. idalia,* 47 males, and 9 females, were caught and marked. Only one individual that had been marked was recaptured. One hundred and ninety-two individuals were seen but undoubtedly some of these were repeat sightings. An alternative source for *S. idalia* females was Rolling Thunder State Preserve (Fig. 1A), a 118-hectare prairie, which supported a relatively large population of *S. idalia* (though smaller than Ringgold).

Females were transported from the source to Neal Smith NWR in late July 2000 and mid August to early September 2001 to coincide with oviposition dates. We removed only one in every ten females caught at Ringgold and Rolling Thunder as a protection of the source populations. Gravid females were transported from the source to Neal Smith NWR in a cool environment in glassine envelopes within 2 hours of capture.

In 2000, four females were moved from Ringgold to Neal Smith NWR and were placed in small 0.6 X 0.6 meter mesh cages directly over a violet plant in four of the violet plots located in the burned and sparse, unburned planting units (these were the areas with the highest violet survival) (Fig. 1B). The reintroduced females were provided with cut flowers for nectar and the cages were moved daily to new violet plants to maximize the distribution of eggs. Survivorship of the females ranged from 3-19 days.

In 2001, the date of introduction was shifted to mid-August/early September (August 19 and September 1) to more closely coincide with oviposition dates because survivorship in captivity was limited. Two female *S. idalia* from Ringgold and one female from Rolling Thunder were transported to two violet plots at Neal Smith in the same manner as 2000 (Fig. 1B). Instead of small cages, introduced females were placed in much larger (1.83 X 1.83 meter) cages on the violet plots, which covered several violet plants and therefore did not need to be moved. Survivorship for the two females from Ringgold ranged from 16 to 20 days. The female from Rolling Thunder disappeared from the cage 5 days after release.

Introduction of female *S. idalia* was not initiated in 2002 because we observed several *S. idalia* on the refuge. From surveys on several other prairies in South-Central Iowa, we ascertained that *S. idalia* were present in areas that previously had not been inhabited and that *S. idalia* was having a particularly high population year. Our observations led us to believe that *S. idalia* may have immigrated into the refuge from nearby areas and may not have been the result of our introduction efforts. We suspected that most of the individuals were immigrants and we did not wish to compromise a possible colonization event by bringing in individuals from a more distant location.

Assessment of Speyeria idalia Introduction

In the spring of 2001 and 2002 we surveyed violets that had been enclosed by a cage that held a gravid *S. idalia* female for larvae and evidence of herbivory. To coincide with the emergence of males, we surveyed for adult *S. idalia* at Neal Smith NWR beginning in mid-June. Surveys were centered on the planting units where introductions were accomplished.

In 2002, when adult *S. idalia* were observed at the refuge, we expanded our search area and initiated a mark-release-recapture program to estimate population size. Three planting units where *S. idalia* were most abundant were surveyed on July 23-July 25, July 28-July 29, August 1 and August 7. Two people walking steadily 10 meters apart surveyed the same area of each of the three units for 40 minutes of active search time (stopwatch was stopped to process individuals). Butterflies were marked with a unique pattern that corresponded to a number using a felt tip marker (Opler & Krizek 1984) and were immediately released at point of capture after recording the sex, activity (if nectaring, the nectar plant was identified and recorded), amount of wing wear, and UTM coordinates of capture location. Surveys were only conducted on warm (not below 18 degrees Celsius), sunny (less than 60% cloud cover), and calm (sustained winds less than 17 kmph) days between 0930-1630 hrs. The number of captures and recaptures was not high enough to calculate an estimate of population size but the information recorded is reported here.

Results

Host Plant Establishment

Total violet survival for 2002 was 72.86 % (Fig. 2). Plots with the highest survival rate were located in the unburned sparse planting treatment area (92.32 %) (Fig. 2). The second highest survivorship was in burned plots (81.62 %) (Fig. 2). Nine new violet plants were recorded within and adjacent to the plots indicating that the violets are propagating.

Speyeria idalia Reintroduction

Surveys for caterpillars in 2001 and 2002 were unsuccessful in locating larvae. Some herbivory was noted on violet plants but we were unable to ascertain the cause of the herbivory. In addition, surveys for adult *S. idalia* were unsuccessful in 2001.

We observed the first *S. idalia* at Neal Smith NWR on 7-5-02. Planting units where *S. idalia* were observed are indicated on figure 1C. Fourteen individual *S. idalia* were caught, marked, and released in three planting units and all these individuals were male. There were two recaptures of the same individual (Table 1). There were also 64 sightings (# of uncaptured individuals) of *S. idalia* in the three planting units used for the mark-release recapture study though some were probably repeat sightings. We marked three additional individuals outside of the three designated sampling areas and saw 20 more (Table 1). We did not have a confirmed observation of a female *Speyeria idalia*, however two individuals were observed near violet plots on August 25^{th}. While some males may persist to this late date (Kopper et al. 2001; Zercher 2001), the likelihood that these individuals were females is high.

Discussion

Major Obstacles

The first obstacle encountered with *S. idalia* was the inability to captively rear individuals for release. Other studies have transported wild-caught adults (Marttila et al. 1997; Wynhoff 1998) but this procedure adds many assumptions. It assumes that the wild-caught individuals will reproduce on the new area (if transporting both male and female). If just moving females, there is an assumption that their eggs have been fertilized before transport. Timing must be scheduled so that females have not finished ovipositing because this status cannot easily be verified before moving the individual.

Introducing large numbers of individuals can compensate for the uncertainties involved with transporting wild-caught adults, as well as complications associated with the loss of genetic heterozygosity (Barascud et al. 1999). However, for *S. idalia* large-scale introduction proved very difficult. Female *S. idalia* tend to be less numerous than males and/or more difficult to find and catch (Nagel et al. 1991, Kelly & Debinski 1998; Kopper et al. 2001). In intensive surveys of eight sites in Iowa, Kelly and Debinski (1998) found only 31 females to 479 males. In the same study, surveys on prairies in Kansas and South Dakota produced higher numbers of females (210 and 296 respectively) than males (150 and 126, respectively) suggesting that the low number of females found in Iowa prairies was not due to sampling bias. We found a similar sex ratio to Kelly and Debinski (1998) in our surveys at Ringgold and Rolling Thunder during 2001 and 2002. Collections of females were not conducted outside of Iowa because Neal Smith NWR is constrained to a 38 county ecotype area for introductions. We were limited to bringing in a few females every year for many years, in a simulation of frequent immigration, in order to encourage a genetically and numerically robust population at the refuge without compromising donor populations. Barascud et al. (1999) found that a reintroduction of *Proclossiana eunomia*, an endangered butterfly, was successful despite low introduction numbers (18 individuals) and a loss of polymorphism. However, it is still important to try and encourage genetic heterozygosity by bringing in females for many years.

Our reintroduction project was further complicated by the appearance of *S. idalia* at the site of reintroduction. The appearance of the desired organism may not normally be viewed as a setback to a reintroduction project, but in this case surveys on other nearby prairies revealed that *S. idalia*'s appearance at the refuge may not have been a result of our reintroduction efforts. In a survey at Ringgold on July 2, 2002, 23 individuals (all males) were caught and marked in two locations and 11 others were seen using a sampling effort of two observers for 30 minutes of search time in each area.

In addition, we observed *S. idalia* during surveys at 14 of 24 other sites (surveyed for another butterfly study), five of which were reconstructions where *S. idalia* had not previously been seen. Four of the five reconstructions where *S. idalia* were found did not support populations of *Viola pedatifida* or *Viola pedata*. This type of population explosion and mass dispersal event in *S. idalia* has not been reported in the literature.

It should be noted that these suspected dispersal events seemed to involve primarily males. *S. idalia*'s dispersal abilities aren't fully understood. Ries and Debinski (2001) found that in Iowa *S. idalia* were reluctant to disperse out of a prairie across tree, crop and field edges. Surveys at Fort Indiantown Gap National Guard Training Center, Zercher (2001) reported that *S. idalia* were capable of dispersing up to six miles in two hours across inhospitable habitat. The majority of the dispersing individuals in the Pennsylvania study were males. The most plausible explanation for dispersal in *S. idalia* is to search for nectar resources (Zercher 2001) but this is unclear and a number of questions are raised. If primarily males are dispersing and the motivation is to locate nectar, are they dispersing after breeding? If some females are also dispersing in search of nectar, are reconstructions containing no host plants but plenty of nectar serving as population sinks? How do *S. idalia* females locate host resources? Placing plots of host plants exclusively in the center of a large reconstruction may not be ideal for colonizing individuals. In the case of our study, how do we determine reintroduction success, when it is unclear whether individual butterflies are immigrants or the first brood of introduced females? Genetic analysis may be one solution but even that may not be definitive.

Lessons Learned

Pullin (1996) and Wynhoff (1998) both stress the importance of detailed knowledge of the species ecology and habitat requirements to the success of butterfly introductions. Our project certainly supports these comments but in unexpected ways.

The problems associated with *S. idalia*'s poor ability to reproduce in captivity and the difficulty in locating abundant females emphasized that species constraints can profoundly affect the length of a reintroduction effort. The limitations of bringing in a few females each year guarantees the project to take many years, if not decades, to complete effectively. Success in our project will require a dedicated and organized effort by Neal Smith NWR and the researchers involved. These problems suggest that it is not safe to assume that introductions of insects will be on a shorter time scale than large animals with longer generation times.

In light of the possible natural colonization of *S. idalia* at Neal Smith NWR there may be no need to continue reintroductions efforts. However, we have no evidence of reproduction on the refuge and immigration of individuals is not confirmed. We have a good deal of information about *S.*

idalia's life history and habitat requirements but with more detailed knowledge of *S. idalia*'s long-term population dynamics and dispersal abilities, we may have chosen a different design for this introduction project. More knowledge would also be useful in predicting what can be expected in the 2003 flight season.

In addition, it is clear that surveys of *S. idalia* populations at other sites in the vicinity of the introduction site were very useful in compensating for some of our lack of knowledge about population dynamics. If we had not been surveying several other prairies, we may have, possibly incorrectly, assumed the reintroduction was initially a success. These other surveys were essential for an honest assessment of our reintroduction efforts.

Another gap in our knowledge was access to the details of other butterfly reintroduction projects. The availability of published information on successful and unsuccessful projects would have been very helpful in planning and assessing this project. Restoration of rare butterfly communities on re-created habitats could be an important tool for conservationists.

In conclusion, our project has emphasized the importance of detailed information on the demography, habitat requirements and dispersal abilities of the target species to a successful introduction. Knowledge of yearly population trends and the ability to adapt to changing circumstances are also essential. This study has detailed some of the problems encountered in our reintroduction but has suggested that in *Speyeria idalia*'s case, reconstructed habitats may be viable options for connecting and enhancing populations.

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Tables and Figures

Table 1. Data from a mark-release-recapture study of Speyeria idalia *at Neal Smith National Wildlife Refuge. Surveys were performed at three sites on the refuge where* S. idalia *appeared most abundant on sunny, calm days(low wind speed). Data were collected on seven days in late July and early August 2002. Numbers of* S. idalia *seen and marked at other locations on the refuge are also reported. Numbers are the total across all sampling days.*

Site	*# of* S. idalia *Observed*	*# of* S. idalia *Captured and Marked*	*# of* S. idalia *Recaptured*
Planting Unit 21	22	5	0
Flaherty	23	6	0
Planting Unit 25	19	3	2*
Other sites	20	3	0
TOTAL	84	17	2

* Both recaptures were of the same individual.

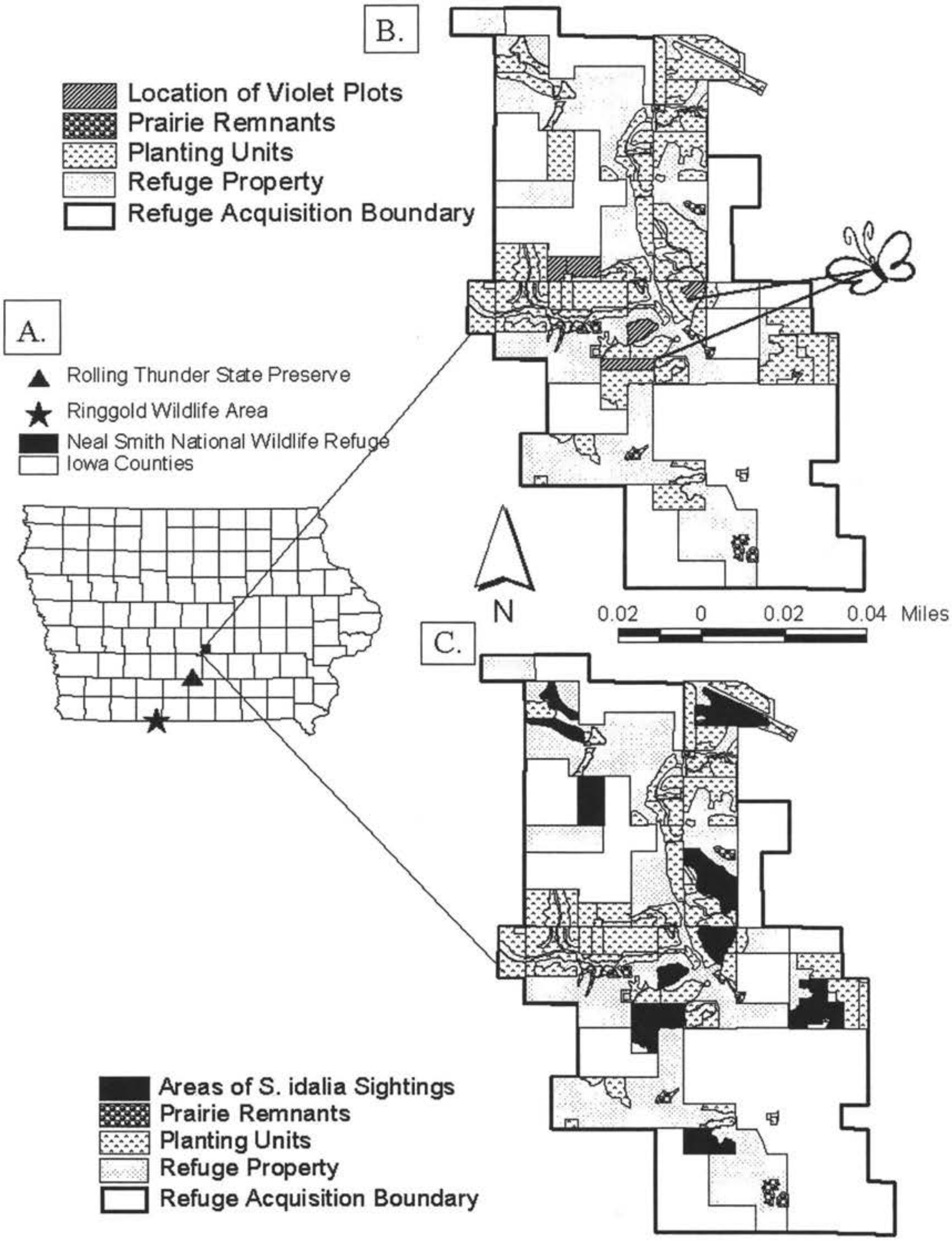

Figure 1. Maps showing the locations of Speyeria idalia *source population and reintroduction locations in Iowa, U.S.A. A) The primary source population was located at Ringgold Wildlife Area. A total of seven female* S. idalia *were moved from Ringgold to Neal Smith NWR. The secondary source population was located at Rolling Thunder State Preserve. One female* S. idalia *was moved from this location to Neal Smith NWR. B) Map of Neal Smith NWR showing the location of remnants, violet plots, and* S. idalia *reintroduction areas in the summer of 2000 and 2001. C) Map of Neal Smith NWR showing locations on the refuge where* S. idalia *was observed in the summer of 2002.*

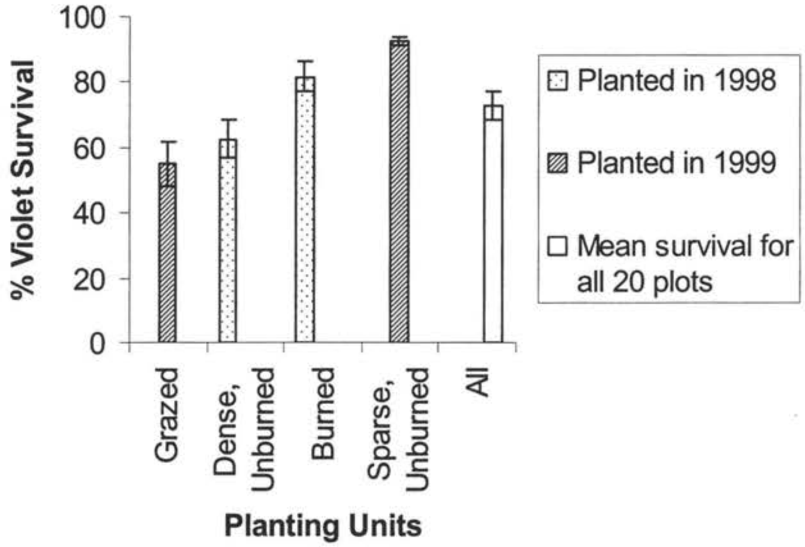

Figure 2. Percent survival of planted Viola pedatifida *plants at Neal Smith National Wildlife Refuge. Each treatment had five plots of 99 plants each planted in either 1998 or 1999. Data presented are the means of the five plots for each treatment and the mean for all plots for 2002. Error bars represent one standard error.*

General Conclusion

The butterfly community

Butterfly richness, abundance, and community composition were limited indicators of vegetative quality on reconstructed and remnant prairies in central Iowa. Results from our study and others (Selser & Schramm 1990; Panzer 1995; Debinski & Babbit 1997; Wheater and Cullen 1997; Brand & Dunn 1998) indicate that plant and butterfly diversity are on average greater in remnant communities versus restored communities. Our study also suggested that butterfly and plant diversity are greater (though this trend was not significant) on integrated reconstructions as compared to isolated reconstructions. Overall butterfly community composition was very similar among remnant, integrated, and isolated reconstructions, however, the richness and abundance of habitat-sensitive butterfly species was significantly higher on remnant prairies versus isolated reconstructions.

Butterfly richness, abundance, and community composition showed little difference among reconstructed prairies exhibiting differing levels of vegetative quality based on plant diversity, the proportion of native plant species, and the average coefficient of conservatism (an index measurement of disturbance-sensitive plant species composition). The primary plant variable (plant diversity, proportion of native plant species, and average coefficient of conservatism) that butterfly richness and abundance correlated with was the average coefficient of conservatism. There was a non-significant trend of higher butterfly richness and abundance on the highest quality reconstructed prairies versus the medium and low quality reconstructions. Butterfly community composition was very similar among different quality reconstructions.

Management of reconstructed prairies, in the form of prescribed burning, did have an impact on the butterfly community. Butterfly richness was significantly lower on sites that were burned in the fall or spring preceding summer data collection as compared with sites that were unburned. Percent cover of the duff layer, a variable that is higher on unburned prairie, was also an important explanatory variable for butterfly richness. These data suggest that prescribed burning of reconstructed prairies may have a greater effect on the butterfly community, at least in the short-term, than the vegetative quality of the prairie.

The vegetative variables that were most predictive of butterfly richness for all prairie sites combined and for reconstructed sites alone, were the number of ramets in bloom (a crude measure of nectar availability), percent cover of duff, and the average coefficient of conservatism. Butterfly richness was positively correlated with ramets in bloom and the percent cover of duff indicating that areas with higher nectar resources and greater cover of dead vegetation (as compared to bare ground) were more likely to support more butterfly species. Butterfly richness was negatively correlated with the average coefficient of conservatism. This pattern was driven by the integrated reconstructions, which had a significantly lower average C but higher butterfly richness than isolated reconstructions. The best model for explaining butterfly abundance was the number of ramets in bloom and the percent cover of duff but this model did not explain a significant amount of variation.

A prairie endemic butterfly

The reintroduction of *Speyeria idalia* into a reconstructed prairie was a project that presented several challenges and obstacles. The first challenge was the difficulty in captively rearing *S. idalia* (Wagner et al. 1997, pers. obs.). The second challenge was locating adequate numbers of wild gravid females at source locations to transport to Neal Smith National Wildlife Refuge (NWR). Donor populations were large but females were difficult to find and catch. Due to low introduction numbers (4 individuals in 2000, and 3 individuals in 2002) establishment of a viable and genetically heterogeneous population of *S. idalia* at Neal Smith NWR, will require many years of introductions. The projected long length of the project runs contrary to what might be expected for the reintroduction of an invertebrate with a short generation time.

A primary obstacle to the introduction project was a lack of detailed knowledge about *S. idalia*'s population cycles, dispersal abilities, and behavior. Surveys on prairies in the vicinity of Neal Smith NWR indicated the occurrence of a *S. idalia* population explosion in 2002, which coincided with the appearance of the butterfly at the refuge. Many *S. idalia* that appeared on the refuge were likely immigrants and were not a result of our reintroduction efforts. Subsequently we made a more cautious assessment of the appearance of *S. idalia* at Neal Smith NWR and were unable to declare the introduction's initial success.

Despite the many challenges and obstacles encountered, it appears that reconstructed prairie may serve as additional habitat for *S. idalia*. *Viola pedatifida*, *S. idalia*'s host plant, was successfully established at the introduction site and adult butterflies were observed at the refuge. Regardless of whether individuals of *S. idalia* were immigrants onto the refuge or the brood of introduced females, our results suggest that reconstructed prairies can fulfill at least some of *S. idalia*'s habitat requirements.

General Conclusion

Butterflies are only limited indicators of vegetative development and success on reconstructed prairies. Their level of mobility and their significant response to management may confound their indicator potential. Examination of all stages in the butterfly life cycle may strengthen the observed response to vegetation but would remove the advantage associated with the easy sampling of adult butterflies. The differences in species richness and abundance on remnant versus reconstructed prairies indicate that most prairie reconstructions in central Iowa have not reached the highest level of butterfly community diversity. In addition, it is necessary to recognize the importance of remnant prairies as refuges and sources for many butterfly species.

The *S. idalia* reintroduction project has emphasized the importance of detailed information regarding demography, habitat requirements and dispersal abilities to a successful introduction. Knowledge of annual population trends outside of the introduction site and the ability to adapt to changing circumstances are also essential. We have detailed some of the problems encountered in our reintroduction project but we suggest that reconstructed habitats may be viable options for connecting and enhancing *S. idalia* populations.

We make the following recommendations for reconstruction projects seeking to foster the butterfly community. Larger reconstructions that incorporate existing remnants will encourage colonization and support greater species richness. Planting prescriptions that incorporate nectar-producing plants that will bloom in succession to cover the entire flight season will encourage greater butterfly species richness. Finally, conservative management with respect to prescribed burning should be favored.

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